THE ORIGIN OF THE MARTIAN INTERCRATER PLAINS: THE ROLE OF LIQUEFACTION FROM IMPACT AND TECTONIC-INDUCED SEISMICITY. S. M. Clifford, Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX, 77058; clifford@lpi.jsc.nasa.gov..

Since images of the Martian cratered highlands were first returned by Mariner 4, investigators have puzzled over the origin of the intercrater plains [*e.g.,* Öpik, 1965; Hartmann, 1966]. The apparent deficit of craters with diameters <30 km within the plains, and the poor preservation state of many the larger craters throughout the highlands, are often attributed to the possible existence of a dense early atmosphere whose presence may have warmed the early climate and accelerated the rates of fluvial and eolian erosion. While such conditions may have existed and contributed to the development of the intercrater plains, the evidence for abundant water in the early crust and the frequency of major seismic disturbances estimated from the planet's impact and tectonic record, suggests another possibility.

Under conditions where the pore pressure of water in a soil exceeds the local lithostatic stress, there can be a sudden and catastrophic loss of soil strength called liquefaction. On Earth, liquefaction is often triggered when a saturated soil experiences a sudden acceleration due to the passage of a seismic sheer or compressional wave. This occurrence can cause massive slumping, folding, and faulting on slopes; violent eruptions of water and sediment; and the formation of extensive collapse depressions arising from the liquefaction and lateral extrusion of susceptible underlying layers. Examples of such phenomena are well documented, having been observed in association with major earthquakes all over the world. In one of the most destructive events on record, flow slides triggered by the 1920 Kansu earthquake (M_w = 7.8) buried ten large cities and numerous villages in an ~$8x10^4$ km^2 area of China, killing almost 200,000 people [*Seed*, 1968]. In areas which have experienced such extensive liquefaction, the landscape is often left as complex mass of depressions and ridges – creating a hummocky texture that closely resembles the appearence of the Martian intercrater plains.

On Mars, the propagation of crustal shock waves, generated by impacts, earthquakes, and explosive volcanic eruptions, are likely to have repeatedly shaken, dilated, and forcefully compressed water-bearing formations on a global basis – producing transient pressures sufficient to cause widespread liquefaction, the disruption of confined aquifers, and the ejection of water and sediment through crustal fractures and pores. During the great Alaska earthquake of 1964 (M_w = 9.2), these processes caused extensive flow slides and resulted in water and sediment ejection from shallow aquifers as far as 400 km away from the earthquake's epicenter, with some eruptions rising over 30 m into the air [*Waller*, 1968].

As discussed by *Golombek et al.* [1992*], Tanaka and Clifford* [1993], and *Clifford* [1993], the Martian geologic record provides abundant evidence that Mars has experienced seismic events of a similar, and sometimes much greater, magnitude. A recent analysis suggests that at the maximum distance that water and sediment ejections were observed during the Alaska earthquake, pore-pressure changes of as much as several bars (200-300 kPa) were generated in near-surface silt and clay sediments [*Clifford and Leyva*, 1997]. On Mars, an impact of equivalent seismic energy (D ~87 km, assuming a kinetic to seismic energy conversion efficiency of 10^{-4}) will produce this same pressure change in a basalt aquifer at a distance of ~225 km, while a 200 km impact (equivalent to an M_w = 10 quake) extends this range to ~1,000 km. For impacts ≥600 km (M_w ≥ 11), pore pressures in excess of 100 kPa are generated on a global scale, with substantially higher pressures occurring within several crater radii of the point of impact and at the impact's antipode.

Terrestrial field and laboratory studies have demonstrated that a soil's susceptibility to liquefaction is dependent on a variety of factors and conditions, including particle size, soil density, extent of lithification, pore and confining pressure, as well as the magnitude and frequency of ground acceleration. All other things being equal, the soils most susceptible to liquefaction are well-sorted angular sands, although soils of virtually any particle size – from clays to gravel – can liquefy under appropriate conditions of pore pressure and confinement. This is especially true in confined aquifers at low elevations, where initial pore pressures may approach lithostatic values.

On Mars, the intense impact and volcanic activity of the Noachian period is likely to have resulted in the production of a several km-thick layer of interbedded ejecta, pyroclastics, lavas, and weathering products [*Clifford*, 1993]. Given a crust with this composition, the presence of abundant water, surface temperatures resembling those of today, and an internal heat flow ~5-6x it present value, conditions were right for the global occurrence of near-surface aquifers confined by up to several hundred meters of frozen ground. Under such conditions, liquefaction generated by the occurrence of more than $3x10^4$ impact events with a seismic energy equal to (or up to 10^6 times greater than) that associated with the 1920 Kansu earthquake [*Clifford and Leyva*, 1997], could well explain both the paucity of smaller craters, and hummocky appearance, of the intercrater plains – and do so without the need to invoke a more massive early atmosphere.

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